Abstract: In this paper, we present the automatic wiper system used to detect rainfall and activate automobile windshield wipers without driver interaction. The system was developed to reduce driving distractions and allow drivers to focus on main task of driving. The distraction eliminated with the development of this system is the manual adjustment of wipers when driving in precipitation. The few seconds that a driver takes their attention off the road to adjust a knob while driving in poor weather conditions could potentially lead to car accidents. The system uses a combination of impedance and piezo-electric sensors to detect rain and its intensity. The system contains a microcontroller that takes in the input signals from the sensors and controls the operation of the windshield wipers based on those input signals.

I. INTRODUCTION

The team developed an autonomous windshield wiper system for automobiles using IR and impedance sensors, a microcontroller, and signal conditioning circuitry. The sensors send an input signal to the microcontroller that controls the wiper motor through interfacing with the automobile wiper control circuitry. The motivation of the project centered on developing a reliable automatic windshield wiper system that is commercially available to a large market of automobile owners. Research was done on similar products in the market and articles from academic sources for the foundation of our design approach.

The project aims to develop an automatic windshield wiper system that automates the process of the driver’s manual response to rain on the windshield. Car manufacturers will be the primary customers for system integration into their future automobile lines, and the secondary customers will be individual automobile owners, using the system as an after-market product.

The National Highway and Transportation Safety Association reports that twenty-six percent of all car accidents are caused by distractions due to talking on cell phones, eating while driving, and other similar distractions that take a driver’s focus off the road. The distraction considered in this project is the adjustment of wiper speed based on the intensity of precipitation falling. By eliminating the need for drivers to adjust wiper speed while driving, the number of accidents caused by distraction can be slightly reduced.

Similar systems are currently installed in some luxury vehicles, but such systems have not reached the massive economy vehicle market.

The low-cost solution proposed by the design will most importantly satisfy the safety and performance requirements needed for the driver at a more reasonable price. The windshield wiper system will manage to do this by combining the performance of an inexpensive infrared sensor and impedance sensors. The project demonstration will determine how our system performs against existing systems, and the cost analysis will compare against the cost of existing products.

There are products similar to the systems that are currently on the market. Existing comparable products on the market include the Rain Tracker system by Opto-Electronic Design, Inc. and the TRW rain sensor. Both the TRW rain sensor and the Rain Tracker detect rain through IR sensors[4] that are located behind the rear view mirror and interpret changes in light patterns that are caused by the precipitation on the windshield.

The improvement of existing windshield wiper systems is still an area of interest for researchers. In 2001, researchers presented a report at an IEEE conference that concentrated on the design and implementation of a rain sensing system. In 2005, they proposed a windshield wiper system that used small cameras installed in cars’ windshield to detect rain.

II. PRODUCT DESCRIPTION AND GOAL

The product goals are given by the following criteria:

- Detect rainfall on windshield
- Detect intensity of rainfall
- Activate windshield wipers automatically once rainfall is detected
- Avoid adverse effects of extraneous and environmental factors
- Meet or exceed the response time of the driver
- Make adaptable to all vehicles
- Develop high reliability (less than five percent intensity detection errors)
- Create with ease of installation

The automated windshield wiper system consists of the following:

- sensors that detect rain and its intensity
- a microcontroller that outputs a control signal to the motor control circuitry
- signal-conditioning circuitry to interface with all the components in system
high, but when water is between the plates, current can flow between the plates, thus decreasing the resistance. This operation allows this design to be used as a rain sensor. The sensor becomes operational when one plate is connected to a power source, and the other plate is taken as the sensor output.

### III. DESIGN APPROACH AND DETAILS

#### A. High Level Function Blocks

The rain detection box contains a series of rain sensors. The data processing unit encloses the microcontroller, and the motor control module is composed of the wiper motor and its control circuit. After establishing the functional diagram, a high level system block diagram was drawn. The second diagram represents a more detailed version of the functional diagram. Fig.1 depicts the contents of each unit. The rain detection unit uses two types of sensors whose outputs are normalized by an input signal module. The data processing is performed by a microcontroller, and its results are fed into an output signal module which is the input to the motor control box. The two signal modules were needed for interfacing between all the units.

#### B. Impedance Sensor

The system detects rain by using two sorts of sensors. One of them is the impedance grid sensor[3] shown in Fig.2. The grid is made of two comb-like copper plates separated by a minimum distance of \( \frac{1}{8}\) in. The sensor is glued to the windshield glass with the help of a strong adhesive material. The thin configuration of the plates allows the wiper to slide over without peeling them off. When the plates are dry, the resistance between the two plates is very high, but when water is between the plates, current can flow between the plates, thus decreasing the resistance. This operation allows this design to be used as a rain sensor. The sensor becomes operational when one plate is connected to a power source, and the other plate is taken as the sensor output.

#### C. Piezoelectric sensor

Piezo is derived from the Greek word piezein, “to squeeze.” Piezoelectric materials produce a voltage when strained. When pressure (stress) is applied to a material it creates a strain or deformation in the material. In a piezoelectric material this strain creates an electrical potential difference, a voltage. The effect is reversible. When an electric potential is applied across two sides of a piezoelectric material, it strains. Both effects were discovered by Jacques and Pierre Curie in 1880-1. The piezoelectric effect is found in materials with a specific electrical crystalline structure. These are known as piezoelectric materials.

#### Table II. Electrical specifications of Piezo Disc

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonant Frequency (kHz)</td>
<td>3.0(+/-0.3)</td>
</tr>
<tr>
<td>Main Capacitance (pF)</td>
<td>360000(+/-30%)</td>
</tr>
<tr>
<td>Feedback Capacitance (pF)</td>
<td>5000(+/-30%)</td>
</tr>
<tr>
<td>Resonant Resistance (ohm)</td>
<td>200</td>
</tr>
<tr>
<td>Max. Input Voltage (V peak-to-peak)</td>
<td>30</td>
</tr>
<tr>
<td>Insulation resistance (Mohm)</td>
<td>100</td>
</tr>
<tr>
<td>Metal Plant Material</td>
<td>Stainless Steel</td>
</tr>
<tr>
<td>Operating Temperature(℃)</td>
<td>-20℃-+60℃</td>
</tr>
<tr>
<td>Storage temperature (℃)</td>
<td>-30℃-+70℃</td>
</tr>
<tr>
<td>Metal Plate Diameter(mm)</td>
<td>34.70</td>
</tr>
<tr>
<td>Metal Plate Thickness(mm)</td>
<td>0.30</td>
</tr>
</tbody>
</table>

![Fig.1 High-level System Block Diagram](image1)

![Fig.2 Three-channel Rain Sensor for Speed Control](image2)

![Fig.3 Piezo disc](image3)
A piezoelectric material cannot be isotropic, or identical in all directions. If there was symmetry in the material there would be no electric polarization yield. The following figure shows three materials. The material in a) is isotropic and yields no resultant electric polarization when a force is applied. The materials in b) and c) yield parallel and perpendicular polarizations respectively when a force is applied.

Fig.4 examples of material polarizations with stress. So if you exert pressure on certain crystals, the molecules will re-align and produce a charge across the crystal. A charge can be read as a voltage. A piezoelectric crystal is like a capacitor that is pressure-sensitive. Therefore: Pressure ➔ Crystal ➔ Voltage

Of the natural piezoelectric materials, the most frequently used are quartz and tourmaline. Of the synthetic materials, those that have been more extensively used are not crystalline but ceramics. These are formed by many little tightly compacted monocrystals (about 1 micrometer in size).

These ceramics are ferroelectrics, and to align the monocrystals in the same direction (i.e. to polarize them), they are subjected to a strong electric field during their fabrication process. The applied field depends on the material thickness, but values of about 10 kV/cm are common at temperatures slightly above the Curie temperature (at higher temperatures they are too conductive). The Curie temperature or Curie point is when the material heats up hot enough so that its properties turn from ferromagnetic to paramagnetic. In other words, if a crystal is heated up above a certain temperature, the polarities of the monocrystals will return to random directions instead of all being organized in one direction. This creates a limiting factor of temperature for piezoelectric materials. Piezoelectric ceramics display a high thermal and physical stability and can be manufactured in many different shapes and with a broad range of values for the properties of interest (dielectric constant, piezoelectric coefficient, Curie temperature, etc.). Their main shortcomings are the temperature sensitivity of their parameters and their susceptibility to aging (loss of piezoelectric properties) when they are close to their Curie temperature. The most commonly used ceramics are lead zirconate titanate, barium titanate, and lead niobate. Polymers are also used as piezoelectric materials. A polymer lacking symmetry known as polyvinylidene fluoride is common because it can be made into shapes that are impossible for solid materials.

The generated voltage from a piezoelectric material can be calculated from the following equation:

\[ V = \frac{P}{S_v} \times D \]

Where \( V \) = Piezoelectric generated voltage (Volts)
\( S_v \) = Voltage sensitivity of the material (Volt *meters / Newton)
\( P \) = Pressure (N/m²)
\( D \) = thickness of material (meters)

Voltage sensitivity values are provided with the material when received from the manufacturer. Different materials and different geometry cuts give different sensitivities.

**Advantages:**
- Low cost
- High sensitivity
- High mechanical stiffness
- Broad frequency range
- Exceptional linearity
- Excellent repeatability
- Unidirectional sensitivity
- Small size

**D. Input Signal Module**

The input signal module’s first function is to normalize all sensor signals so that the microcontroller can safely interface with the rain detection unit by limiting the amount of incoming current.

In addition, it hosts the user-controlled sensitivity circuits. Each sensor is dedicated a separate part within the input signal module. Error! Reference source not found. shows the internal circuit corresponding to the impedance grid sensor. All other sensors have a similar input circuit.

The sensitivity is controlled by a potentiometer that can be manually tuned by a user. The protective resistor below the potentiometer makes sure that the overall system remains stable and functional regardless of users’ settings. The capacitor introduces a low-pass filter that helps stabilize the sensor output so that the microcontroller makes more accurate readings. The input circuit also solves the floating voltage problem discussed earlier by providing a ground between the sensor and the microcontroller.

**E. Microcontroller and Control Logic**

The data processing unit is composed of a microcontroller and an output signal module. The AVR Atmega8 microcontroller was finally selected over the initial TI MSP430 because of its higher output power and number of analog-to-digital channels [6]. The communication between the computer programmer and the microcontroller is done via serial peripheral interface bus (SPI). The program executed by the microcontroller is shown in fig.5.
Once the system is enabled, the system initialization block checks if the sensors are operational, sets the corresponding input and output pins, and determines if the power is high enough to keep the microcontroller running. After performing all the necessary checks, the program reads voltages from the impedance grid sensor and IR sensor in a sequential order. If water is detected, the microcontroller sends a signal to a power relay so that the wiper motor is activated at its lowest speed. Afterward, the microcontroller reads the speed control sensor and determines the appropriate motor speed by powering other relays. The additional relays affect change the amount of power going to the motor. The loop continues as long as all the sensors detect water on the windshield.

In addition, the team would schedule project milestones differently taking into consideration parts of the project that were most significant and consequently required the most effort to complete. The initial goals and objectives were to expand upon existing automatic windshield wiper technologies to make a more reliable yet economically priced system. As shown by the project demonstration and the cost analysis, these goals and objectives were met. Recommendations for future versions of the product include using more sophisticated IR sensors, including a voice recognition feature, and raising all the power windows in the vehicle when rain is detected. Although the project met our goals, another production cycle should be initiated to improve the reliability of the system and include the features mentioned in the future versions.

Fig.5 Summary of System Control Logic

F. Output Signal Module

The output signal module is the bridge between the design system and the existing automobile windshield wiper system. Figure depicts how the microcontroller is connected to the relays driving the motor control board.

The control process for the project stops after the output signal module because the motor control unit is foreign to the system. However, for installation purposes, the user should be able to integrate the design product to an existing automobile. Therefore, only general interfacing information is required to be provided to the user. However, in order to demonstrate the overall project, a motor and a control module circuit were acquired and tested.

IV. CONCLUSION

In conclusion, the automated windshield wiper system was designed, developed, and demonstrated to detect rain and actuate the automobile windshield wipers based on the intensity of that rain. The demonstration is able to simulate the operation of the system as if installed in an automobile. The team was able to successfully complete the project and satisfactorily meet the proposal goal of automating the driver’s response to rain within the specified amount of time of 500 milliseconds. Though the system functioned as desired, in retrospect then I would have selected different design approaches. After noticing that more accuracy was required from the IR sensor to adequately detect the intensity of rain the team would have selected a more applicable IR sensor.